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BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

PAPER IN THIS NUMBER.

"Characteristics of Some Connecticut Sludges." By J. Frederick Jackson and J. Doman.

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Contributors are hereby notified that proof will not be submitted to them for examination unless requested before the 10th of the month preceding the month of publication.

MINUTES OF MEETINGS.

BOSTON, January 25, 1922. A regular meeting of the Boston Society of Civil Engineers was held this evening in Chipman Hall, Tremont Temple, and was called to order at 7.50 P.M. by the President, Robert Spurr Weston.

There were 55 members and guests present.

The minutes of the meetings of December 21st and 28th were read and approved.

The Chairman announced that the Board of Government had elected to membership the following candidates in the grades named:

Honorary — Mr. William Edward McClintock.

Members — Messrs. Erol G. Dary, Frank L. Flood and Winthrop E. Nightingale.

Juniors — Messrs. George L. Burke, Walter H. Lee, Edward B. Murdough, Chester L. Nyman, Roger G. Oakman, Alfred D. Parsons, Samuel A. Riggio and Herman C. Stotz.

The President announced the death of Charles A. Pearson on December 11, and was authorized to appoint a committee to prepare a memoir.

The Secretary presented a memoir of Richard Hutchinson which had been prepared by Mr. I. E. Moulthrop. The memoir was accepted and ordered printed in the Journal.

The President announced that the Legislative Committee had studied the subject matter of Bill 7541, which is before the House of Representatives in Congress, providing for the commissioning of engineers in the Public Health Service, and it had recommended the passage of the following resolution:

"Resolved, that the Boston Society of Civil Engineers endorse the Congressional Bill, H. R. 7541, giving a commissioned status to Sanitary Engineers in the Public Health Service of the United States."

The Board of Government at its meeting on December 21st,

"Voted, that the resolution be reported to the Society with the recommendation that it be adopted."

The President stated that notice of this had been sent out with the notice of the regular meeting as prescribed by the By-Laws, and that if adopted by the meeting would be sent out to the membership on letter ballot. He further stated that unless it was otherwise directed, the action of the Society could be reported to the Federated American Engineering Societies for the necessary action. Thereupon the resolve was unanimously adopted.

The President then described the work that had been done towards the formation of an affiliation of technical societies in Boston, and stated that the question would be presented before the Society at its next meeting.

Past President Howe addressed the Society and requested that additional funds be subscribed towards the Tinkham Memorial.

Mr. Thomas C. Atwood of the T. C. Atwood Organization of Raleigh, N. C., then presented a paper entitled "Special Methods of Handling Cost Plus Work for a Southern University." The paper was illustrated with lantern slides.

Adjourned.

RICHARD K. HALE, *Acting Secretary.*

BOSTON, January 11, 1922. A regular meeting of the Designers Section was called to order this evening in the Society Rooms, at 6.10 o'clock, by the chairman, Ralph E. Rice.

The subject of the evening was "Heating and Ventilating." Mr. A. C. Bartlett, Ventilating Engineer and Secretary of the Boston Chapter, American Society of Heating and Ventilating Engineers, was introduced and addressed the section on "What is Ventilation?" outlining the progress of the art from its earliest development down to the most modern conception.

He was followed by Mr. F. O. Alden, Sales Engineer for the Pierce, Butler and Pierce Manufacturing Corporation, who gave many practical suggestions for the design and installation of the various modern systems of heating and ventilation, and urged coöperation between architect and heating and ventilating engineers in the very early stages of building design, in order to avoid later difficulties in accommodating suitable devices to the space provided.

Thirty were present at this most instructive meeting, which was adjourned at 7.40 P.M.

ARTHUR L. SHAW, *Clerk.*

APPLICATIONS FOR MEMBERSHIP.

[February 15, 1922.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

BLANK, WESLEY HOWARD, Winchester, Mass. (Age 27, b. Winchester, Mass.) Graduated from Mass. Inst. of Technology in civil engineering, in 1916, with degree S.B. From June, 1916, to September, 1918, was draftsman with McClintic, Marshall Co., Pottstown, Pa.; September, 1918, to December, 1919, was a lieutenant in charge of an Anti-Aircraft Battery in France; January, 1920, to September, 1921, designer, estimator and structural engineer with Shoemaker Satterthwait Bridge Co., Pottstown, Pa. During the latter part of this last period was engaged on bids for sales department and had complete charge of preparing designs. He resigned the above position to take up advanced work at college and later to go into business, and accepted a position as instructor in Bridge Design at Mass. Inst. of Tech., where he is at present engaged. Refers to H. K. Barrows, G. A. Sampson, C. M. Spofford and C. H. Sutherland.

DICKSON, ARTHUR DONOHUE, Newtonville, Mass. (Age 29, b. Cambridge, Mass.) Graduate of Mass. Inst. of Tech. in 1917, with degree of S.B. in civil engineering. For a year and a half before entering preparatory school was office assistant and assistant foreman with George W. Macauley; assistant superintendent of construction with Stone & Webster at Falls Village, Conn., during the summer of 1916; during the war was second lieutenant in the Coast Artillery Corps, Regular Army, and later was promoted to rank of captain; in January, 1919, became assistant structural sales agent with the Bethlehem Steel Co., and assistant sales engineer, Bethlehem Steel Bridge Corp., New England district, and recently promoted to structural agent and sales engineer for the district. Refers to H. P. Eddy, Jr., J. W. Howard, C. M. Spofford, E. D. Storrs and J. W. Storrs.

GANNON, GEORGE H. P., Cleveland, O. (Age 26, b. Clinton, Mass.) Graduate of Worcester Polytechnic Institute in 1917. From May to Sept., 1917, was a designer at Colts Patent Fire-arms, Hartford, Conn., from Sept., 1917 to Sept., 1918 chief tool designer with a firm in Dayton, Ohio; during the war he was a secret service agent in munition plants; instructor in machinery design and kinematics in Cleveland, O., in 1918; assistant mechanical engineer from May, 1919 to the present with the National Lamp Works, Cleveland, O. Refers to the Cleveland Engineering Society.

HANLEY, JOHN MERRILL, Milton, Mass. (Age 24, b. Dorchester, Mass.) Graduated from Mass. Institute of Technology in 1918, with degree from M. I. T. and Harvard Engineering School of B. S. Summer of 1917 was a rodman with the Metropolitan Water Works, also spent two weeks at Technology Engineering Camp as assistant instructor in surveying; during the spring

of 1918 was assistant instructor in surveying at Mass. Institute of Technology, Cambridge, and in the fall of 1918 was in the Coast Artillery School at Fortress Monroe and received commission of second lieutenant; from March 1919 to Aug., 1919 draftsman and surveyor with the inspection department of the Associated Factory Mutual Fire Insurance Co's.; from Aug., 1919 to Sept., 1920 assistant engineer on automatic sprinklers, layouts and approval of plan and installations; from Sept., 1920 to the present, editor of special inspection reports on Fire Protection with rating of assistant engineer. Refers to J. B. Babcock, H. L. Carter, J. W. Howard, C. M. Spofford.

HOBBS, SAMUEL, Reading, Mass. (Age 30, b. Pelham, N. H.) Graduated from the Nashua, N.H. High School in 1907 and from Dartmouth College, with the degree of B.S. in 1912, and from the Thayer School of Engineering connected with Dartmouth College, in 1913, with the degree of C.E. From May to September, 1912, served as inspector at the Asphalt Mixing Plant, Nahant, on the construction of the Lynn-Nahant boulevard. After graduation entered the employ of the Mass. Highway Commission and continued there as a resident engineer on contract construction work until September 1, 1919, under F. C. Pillsbury, Division Engineer; since that time has been engaged in estimating and supervising work for Rowe Contracting Co., also had charge of construction of the Hingham-Norwell concrete road on the Plymouth highway and various other street construction contracts with the State Highway Division, Metropolitan District Commission, City of Boston, etc. At present is with the Rowe Contracting Co. Refers to R. W. Coburn, A. W. Dean, A. P. Rice, R. J. Rowe, J. A. Tomasello, R. E. Whitney.

WILKINS, HENRY MUNROE, Marblehead, Mass. (Age 22, b. Marblehead, Mass.) Graduated from the High School in Marblehead in 1917 and entered Northeastern College in September of that year. During the five-week work periods has been employed as rodman and transitman with Whitman & Howard, as transitman with Aspinwall & Lincoln; in the engineers office of the Land Court, Commonwealth of Massachusetts, as computer; graduated from Northeastern College in June, 1921, since which time he has been with the Mass. Highway Commission as civil engineer Grade B, doing general office work and as inspector on a bituminous macadam road. Refers to C. S. Ell, C. Howard, L. B. Hoyt, C. B. Humphrey, E. H. Lincoln.

LIST OF MEMBERS.

ADDITIONS.

AIMO, KARL H.	56 Riverdale St., Allston 34, Mass.
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WILLIAMS, W. QUINTIN.	1003 Rue de Quai, Port-au-Prince, Haiti.

CHANGES OF ADDRESS.

COLE, HAROLD S.	74½ East Main St., Amsterdam, N. Y.
DURGIN, CLYDE M.	Care Narragansett Electric Light Co. 360 Eddy St., Providence, R.I.
EISNOR, JOHN J.	19 Day St., West Somerville, Mass.
GARVEY, JOHN C.	520 Lake Drive, Milwaukee, Wis.
KLINK, NASSIME S.	314 Faneuil St., Brighton 35, Mass.
MACLEAY, FRANCIS R.	511 State House, Boston, Mass.
MCCORKINDALE, RALPH I.	69 Sycamore St., Holyoke, Mass.
RABLIN, JOHN R.	1 Ashburton Pl., Boston 9, Mass.
WORCESTER, ROBERT J. H.	Care Lockwood, Greene & Co. Box 613, New Braunfels, Tex.

DEATH.

PEARSON, CHARLES A.	December 11, 1921.
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LIBRARY NOTES.

BOOK REVIEW.

"PRACTICAL LEAST SQUARES," by Professor Ora M. Leland, New York, 1921. McGraw-Hill Book Company, Inc. 251 pages, 48 cuts.

REVIEWED BY GEORGE L. HOSMER.*

This book is planned so that the essentials of a course in the adjustment of observations can be taught to engineering students in about 16 lessons. The introduction of so many new subjects into the curriculum of engineering schools has either crowded out the subject of least squares entirely or reduced the available time to a few hours. It is only by careful planning and with a suitable text-book that good use can be made of so short a time. The arrangement of this book seems to be admirably adapted to meet these conditions.

The first six chapters deal with the adjustment of observations of the sort likely to be made by the engineer. This is the most important part of the subject from the practical standpoint. If the time devoted to the course were so limited that only this portion of the book could be studied, the student would have a good idea of what is to him the most important branch of least squares. If time permits, however, the course may be made to include a brief discussion of the determination of the constants in empirical formulas, to which one chapter (VII) is devoted, and the computation of the precision measures of the adjusted quantities and the rejection of doubtful observations, which are covered in chapters VIII and IX. All matter not immediately necessary for the determination of the most probable values of measured quantities is put at the end of the book.

The statements and explanations are written in a clear style which the student can easily follow. The descriptions of the process of eliminating the unknowns in the normal equations and of the (Doolittle) abridged method of solution are particularly clear. Throughout the book there are good practical suggestions for the arrangement of the calculations and methods of carrying

* Associate Professor of Topographical Engineering, Mass. Inst. of Tech., Cambridge, Mass.

out the solution; these should be helpful to the student. A single careful reading of the book reveals very few typographical errors. The experienced computer might be tempted to criticize the length and amount of detail of some of the explanations, but the student who is puzzling for the first time over the formation and solution of normal equations or the selection of condition equations will need all these helps even if he does not appreciate their value. This book should appeal to all those instructors who face the task of teaching the subject of least squares in a very limited number of exercises. For the student intending to go more deeply into the matter this book ought to serve as an easy introduction to the more elaborate treatises.

RECENT ADDITIONS TO THE LIBRARY.

U. S. Government Reports.

Chief of Engineers, U. S. Army, Report of. Parts 1 and 2. 1921.

State Reports.

Massachusetts. Report of Department of Public Utilities. Vol. 2 1920.

Municipal Reports.

Erie, Pa. Annual Report Commissioners of Water Works. 1920.

Manchester, N. H. Report on Sewerage. L. H. Shattuck, Inc. 1921.

Miscellaneous.

Mineral Production of Canada. 1920.

Production of Coal and Coke in Canada. 1920.

Sewage and Sewage Disposal. Metcalf & Eddy. Gift of Publisher.

Westinghouse, George, Life of Henry G. Prout. Gift of Clemens Herschel.

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PAPERS AND DISCUSSIONS

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CHARACTERISTICS OF SOME CONNECTICUT SLUDGES.

By J. FREDERICK JACKSON AND JOSEPH DOMAN*

(Presented before The Sanitary Section, January 4, 1922.)

ONE very important feature in the design and operation of sewage treatment works, and one heretofore too often given the least consideration, is the treatment and disposal of the sludge. No investigation of sewage from large cities can to-day be considered complete that does not include a careful study of the economic treatment and utilization of the sludge. The feasibility of recovering nitrogen and extracting grease from sludges, burning for fuel value or developing gases for generation of power has been at times demonstrated with varying degrees of success, but where such utilization was practiced, local conditions were particularly favorable and a successful method of general applicability still remains to be found. In fact, local conditions and requirements, rather than sludge utilization, govern the selection of sewage and sludge treatment for any particular community.

The importance of returning nitrogen to the soil in order to increase the food supply has been emphasized by scientists all over the world and considerable research work has been done in trying to obtain plant nitrogen from the atmosphere and also from sewage. To support the contention that available nitrogen is being wasted, figures are often given, the significance of which because of their magnitude cannot be quickly grasped, and

* Director and Assistant Engineer respectively, Conn. State Department of Health, Hartford, Conn.

TABLE I.
SLUDGE ANALYSES

Sludge	DRY BASIS TESTS				PER MILLION GALLONS SEWAGE									
	Specific Gravity	% Moisture	% Mineral	% Volatile	% Nitrogen	Ether Extract		Cu. Ft. Wet Sludge	Lbs. Susp. Sol. Re-moved from Sewage	Lbs. Dry Solids in Sludge	% Recovery Suspended Sol.	Lbs. Nitrogen in Sludge	Lbs. Plain Ether Ext. in Sludge	Lbs. Acid Ether Ext. in Sludge
						% Plain	% Acid							
NEW BRITAIN														
Grit Chamber. Grit.....	1.36	52.3	74.8	25.2	0.70	2.9	6.6	0.18	...	6.0	...	0.42	0.17	0.40
Grit Chamber. Scum.....	.98	52.1	20.2	79.8	0.68	62.7	66.5	0.38	...	6.7	...	0.46	4.21	4.56
Screenings. $\frac{1}{16}$ " x $\frac{1}{8}$ " Slots.....	1.08	81.0	...	...	...	...	...	30	...	380	...	...	67.2†	...
Imhoff Tank.....	1.05	90.0	48.3	51.7	2.37	14.3	10.5	72†	525†	470†	89.5†	11.1†	...	01.5†
Secondary Tank.....	1.03	93.8	51.5	48.5	2.88	12.0	22.8	94	380	383	100.7	11.0	46.0	87.3
Total Imhoff and Sec. Tank.....	...	...	...	...	...	...	...	166	905	853	94.3	22.1	113.2	178.8
Activated Sludge*.....	1.004	99.56	35.4	64.6	4.10	13.0	19.3	2950	859	810	94.5	33.2	105.3	156.2
Miles Acid.....	1.025	95.0	26.5	73.5	3.10	21.6	30.3	95	767	308	40.1	9.6	65.3	93.4
SOUTH MANCHESTER														
Plain Sedimentation.....	1.025	95.6	26.6	73.4	4.62	29.2	37.5	162	470	455	96.8	21.0	132.8	170.5
Lime Treatment.....	1.03	95.5	39.5	60.5	1.48	21.3	...	607	524	1700	...	26.0	374.5	...

*Untreated.

†After 3 months' storage.

they weaken rather than strengthen the argument. When we are told, however, that in the maximum consumption of fertilizer in the world of 1 300 000 tons per year only a third is from artificial sources, and when we consider further the recurring food problems of Europe and Asia, and that about 5 000 000 tons of nitrogen per year are wasted from the human body, we are impressed with the fact that there is a great field for the engineer and chemist in developing methods for conserving this waste. Sewage sludges, however, as we know them, are of such composition and characteristics that we have been able to recover and use only an insignificant part of their valuable constituents. In most cases we have been content if we obtained fairly inoffensive sludge disposal.

In our study of Connecticut sludges produced at sewage experiment stations, many points of interest have been noted regarding composition, treatment and possible utilization, and it is the purpose of this paper to discuss briefly some of these.

TABLE 2.

SEWAGE ANALYSES

P. P. M.

Determination	New Britain	South Manches- ter
Nitrogen as Organic.....	12.9	17.7
Nitrogen as Free Ammonia.....	13.2	7.2
Nitrogen as Nitrites.....	.25	0
Nitrogen as Nitrates.....	1.93	0.57
Oxygen Consumed.....	43	141
Total Suspended Solids.....	129	183
Volatile Suspended Solids.....	93	154
Chlorine.....	40	45
Alkalinity.....	118	70

Analytical data concerning these sludges is found in Table 1, while Table 2 shows the composition of the sewages from which the sludges were produced.

GRIT CHAMBER, NEW BRITAIN. COMPARISON OF GRIT AND SCUM.

The grit chamber at the New Britain station treated an average of 90 000 gallons per day, with a retention period of half a minute, inlet velocity of .4 ft. per second, outlet velocity .9 ft. per second. A small baffle across the outlet end retained considerable scum on the surface of the chamber. The grit was black in color, very odorous, and at times contained comparatively large amounts of matter other than true grit, such as spaghetti and pieces of vegetables. The scum differed in appearance from time to time, frequently resembling a heavy dark oil and at other times a dark yellowish grease. It usually had a stale greasy odor.

The grit and scum were practically identical in moisture content, which was very low, averaging about 52%, and in nitrogen content, which was also very low, averaging about .7 of 1%. There was, however, a marked difference between them in other constituents. Of the grit, 75% was mineral matter, while the scum contained 80% volatile matter. Ether extract, both plain and acid, were at least ten times higher in the scum than in the grit. Theoretically, the scum should be quite valuable from the standpoint of grease extraction, as it contained 63% plain ether extract. Actually, however, the amount of scum was so small that only 4.2 lbs. of plain ether extract would be produced per million gallons sewage, or about 16 lbs. per day, from the total New Britain sanitary sewage.

Drying on sludge beds and dumping on spoil land would be the simplest method of disposal of both grit and scum. After drying on the beds, the scum, however, could probably be mixed with coal and burned under boilers, as the amount of volatile matter would be very high and the moisture quite low.

SCREENINGS

A seven-day performance test was made on the New Britain sewage, using a standard Dorrco drum screen with slotted perforations $\frac{1}{16}$ th inch by $\frac{1}{2}$ inch and screening the total daily flow of 3.3 million gallons per day. On the million-gallon basis 30 cu.

ft. of wet screenings were obtained with the comparatively low moisture content of 81%. These were quite dry and in spadable condition as delivered by the bucket elevator. Dry solids amounted to 380 lbs. per million gallons, representing a removal of 21.3% of the total suspended solids from the crude sewage.

The screenings, gray in color, were a mixture of all sorts of sewage solids often containing considerable garbage. When spread on the ground, the screenings dried quite rapidly but with a pronounced foul odor in the immediate vicinity during the first three or four days drying. Flies bred profusely, indicating the necessity of treatment with a fly repellent while drying. At the present time the screenings are disposed on spoil land without any preliminary drying on beds. This method appears quite satisfactory.

IMHOFF TANK SLUDGE, NEW BRITAIN.

As drawn from the tank, this sludge was a thick black liquid having a tarry and somewhat offensive odor. Moisture content ranged from 84.8% to 92.6%, averaging 90%. There was no marked progressive loss in percentage of moisture with storage. From the dry basis tests, the various constituents of the sludge remained quite uniform throughout a storage period of about a year. Of the dry solids, 48.3% were mineral matter, 2.37% nitrogen, 14.3% plain ether extract and 19.5% acid ether extract. From volumetric measurements, combined with specific gravity and moisture tests, progressive digestion was noted with storage. Comparatively fresh sludge, after three months' storage, amounted to 72 cu. ft. per million gallons, which at the end of one year's storage was reduced to 46 cu. ft. Dry solids in the fresh sludge amounted to 470 lbs. per million gallons and after one year's storage to 322 lbs. Comparing the sludge solids with the amount of dry solids removed by the Imhoff tank, as shown by the suspended solids tests, the digestion of solids amounted to 36% after one year's storage.

With regard to moisture, mineral matter and nitrogen content, the Imhoff tank sludge at New Britain was almost identical with that obtained at Worcester, Mass., and Baltimore, Md. It is particularly interesting to note the very small difference in the

nitrogen content of these sludges, that at New Britain being 2.37%, Worcester 2.63% and Baltimore 2.75%.

At New Britain, the sludge dewatered very readily on drying beds. In one of the experiments during the summer the sludge was applied to a depth of twelve inches on the beds and was removed in spadable condition after two days' drying.

SECONDARY TANK SLUDGE, NEW BRITAIN.

This sludge was obtained from plain sedimentation of the sprinkling filter effluent. The retention period in the tank was about one hour. The sludge was very similar in appearance, though noticeably more putrescible than the Imhoff tank sludge. There was but little difference in chemical composition of these two sludges. The tank was cleaned at intervals of from two weeks to two months, and therefore comparatively little sludge digestion would be expected. The dry solids recovered in the sludge were practically identical in amount with that removed from the filter effluent after passage through the tank. The dry solids recovered in the sludge amounted to 383 lbs. per million gallons, the suspended solids removed from the filter effluent to 380 lbs. per million gallons. The volume of wet sludge per million gallons sewage amounted to 94 cu. ft., this being about 20% greater than that from the Imhoff tank.

The sludge dewatered readily on sludge drying beds, but in actual practice it could be returned to the digestion chamber of the Imhoff tank and allowed to digest with that sludge prior to drying on beds.

MILES ACID SLUDGE, NEW BRITAIN.

This was a rather thick, gray, greasy liquid with a pronounced foul odor. The moisture content averaged 95%. Averages on the dry basis were, nitrogen 3.1%, plain ether extract 21.6%, acid ether extract 30.3%.

A peculiar feature of the Miles acid sludge was its low dry solids content. The suspended solids tests on the sewage influent and effluent showed that the dry suspended solids removed from the sewage amounted to 767 lbs. per million gallons, while

the dry solids in the sludge were only 308 lbs. per million gallons, or 40.1% of the suspended solids removed from the sewage. There may have been some sludge digestion, but in view of the germicidal action of the acid and the absence of any gas bubbles rising to the surface of the tank, digestion, if any, must have been very slight. It is very probable that the dissolving action of the acid removed considerable of the suspended solids from the sewage, these passing off in solution in the effluent and not being recovered in the sludge. This would seem to be borne out by the iron determinations. The weighted average of all the Miles acid runs showed that the effluent contained 7.8% more iron than the influent, and while iron precipitates could be observed in the influent they were not observed in the effluent, being obviously in the dissolved form in the latter. The increase in iron content was traced to the action of the acid in attacking iron piping in the tank, parts of which were completely eaten away.

Another indication of the solvent action of the acid on suspended matter is by comparison with the results from the Imhoff tank. This removed 44.8% of the suspended matter and 25.8% of the organic nitrogen from the sewage, very little of the organic nitrogen changing to the ammonia form. The Miles acid process, on the other hand, removed 76.5% of the suspended solids, and as judged by the Imhoff tank removals, we would expect a removal of 44% of organic nitrogen. The actual removal of organic nitrogen, however, was only 7.3%, the effluent containing 92.7% of that in the crude sewage. We can account for this in no other way than by the solvent action of the acid on some of the suspended solids which prevented their precipitation.

The Miles acid sludge dried very slowly and with considerable odor on well-drained sludge beds.

PLAIN SEDIMENTATION AND LIME TREATMENT, SOUTH MANCHESTER.

The tank retention period for both treatments was approximately four hours. Lime dosage was 0.2 gram per liter or 1660 lbs. per million gallons. From the standpoint of sewage purification, there was very little difference between these two treat-

ments, but in several respects the sludges were quite dissimilar.

Lime treatment produced about three and three quarters times as much sludge as plain sedimentation, the figures per million gallons being 607 cu. ft. and 162 cu. ft. respectively. The dry solids in the sludge were in about the same proportion, lime treatment producing 1760 lbs. per million gallons, plain sedimentation 455 lbs. Nitrogen concentration, however, was considerably higher in the plain sedimentation than in the limed sludge, the figures being 4.62% and 1.48% respectively. At the same time there was but little difference in the total amount of nitrogen recovered in the sludges per million gallons of sewage, lime treatment producing 26 lbs. and plain sedimentation 21 lbs. The difference in concentration is obviously due to the large amount of non-nitrogenous precipitates from lime treatment.

ACTIVATED SLUDGE, NEW BRITAIN.

At the present time activated sludge is the most interesting of all sewage sludges on account of its possible utilization as a fertilizer base and also on account of the difficulty experienced in economically dewatering it. But little attention, however, has been given to some phases of the actual derivation of this sludge, and a brief discussion of these may be helpful in our understanding of the changes which take place in it.

With the exception of chemically precipitated sludges, sewage sludges are the result of the removal of suspended matter from the sewage. Activated sludge, however, in our opinion, is derived from some dissolved as well as the suspended matter, and if this is true it will explain some things in connection with the digestion of activated sludge and fixation of nitrogen from the air by certain sludge organisms which heretofore have not been satisfactorily accounted for.

In relation to the precipitation of dissolved organic matter into the sludge, the following figures are rather suggestive. Based upon the results from the Imhoff tank an 80% removal of suspended solids from the sewage would effect a removal of 46% of organic nitrogen. Actually, however, with about 80% removal of suspended solids by the activated sludge process we find a

corresponding removal of nearly 70% of organic nitrogen, or about 52% greater than the expected removal if the organic nitrogen were derived entirely from the suspended solids. Digestion or oxidation may account for some of this extra removal, but it seems much more likely that it is due to the assimilation of the dissolved organic nitrogen by the sludge organisms.

Taking the figures for oxygen consumed, we would expect, with 80% removal of suspended solids, 39% removal in the oxygen consumed. Actually, however, we find that the activated sludge process effects a removal of 65% in the oxygen consumed figure with 80% removal of suspended solids. In this case, also, oxidation and digestion may account for some of this removal but it seems more logical to assume that the assimilation of organic matter originally in the dissolved form in the sewage is responsible for the high reduction in the oxygen consumed figure.

The question of removal of dissolved organic matter can, of course, be settled quickly by comparing amounts and removals of matter in solution and suspension as well as total constituents, but unfortunately all the data at hand give results on total constituents in the sewages and effluents, and no attempt has been made to segregate them into the dissolved and suspended forms. If studies along these lines were available, our knowledge of this phase of the activated sludge process would be much more definite than it is now.

If we admit, however, that dissolved organic matter is removed from the sewage, it seems logical to assume that it has been assimilated by the sludge organisms as part of their food supply. This would very naturally affect computations pertaining to sludge digestion. If we base these computations on the removal of suspended solids only from the sewage, we find a very low percentage of digestion, the figures for Chicago and New Britain being 5.0% and 5.5% respectively, and from the intense biologic action in the sludge we would naturally expect digestion of sludge solids to be considerably greater.

Further, the question of digestion is important from the standpoint of fixation of nitrogen from the air by certain sludge organisms, some investigators having found that some of the

organisms often present in activated sludge actually possess the power of fixing nitrogen from the air. In judging fixation, a nitrogen balance is computed and if the amount of nitrogen recovered is less than the input, it has been customary to assume that there has been no fixation of nitrogen from the air. However, it is still quite possible that there may have been some fixation, but that the digestion has been so great as to offset the recovery of nitrogen from the sewage and the atmosphere. It is interesting in this connection to note that while digestion, both at Chicago and New Britain, amounted to about 5% of the suspended solids removed from the sewage, the actual loss of nitrogen at Chicago was greater than 30% and at New Britain amounted to 20%. If we attribute this loss to digestion, as seems logical, we must conclude that the percentage digestion cannot be computed from the suspended solids alone but that allowance must also be made for the dissolved solids assimilated by the sludge organisms.

As removed from the settling tank at New Britain, the activated sludge was usually reddish brown in color, due to the iron in the crude sewage. During prolonged periods of low iron content in the sewage, the sludge was gray in color, not unlike the slime characteristic of sprinkling filters receiving purely domestic sewage. The sludge was well flocculated but contained a noticeable amount of grit and coarser solids, such as pieces of paper and vegetables. These latter no doubt were due to the fact that the sewage was not screened prior to activation. As wasted from the settling tank, the sludge was found to be quite light, with a specific gravity of 1.004. Moisture content was very high, averaging 99.56%. About two thirds of the dry solids were volatile. Nitrogen content was comparatively low as compared with most activated sludges, averaging 4.1%. Plain ether extract amounted to 13.0%, acid ether extract 19.3%. A comparatively large volume of sludge was produced, averaging 22 100 gallons, or 2 950 cu. ft. per million gallons sewage. Dry solids, however, were comparatively low, averaging 810 lbs. per million gallons sewage.

The most effective treatment and disposal of activated sludge is by no means a settled question, and considerable ex-

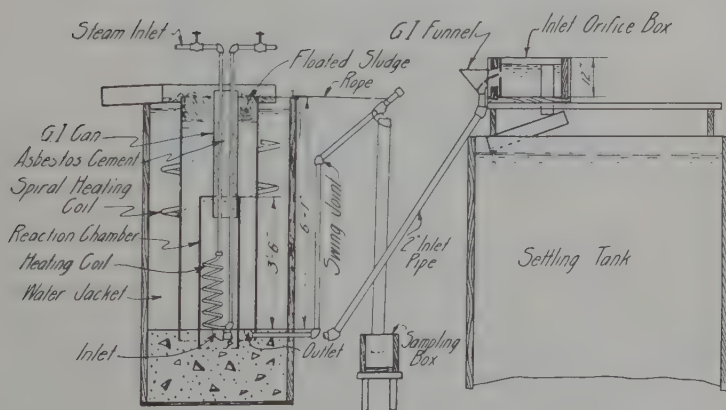
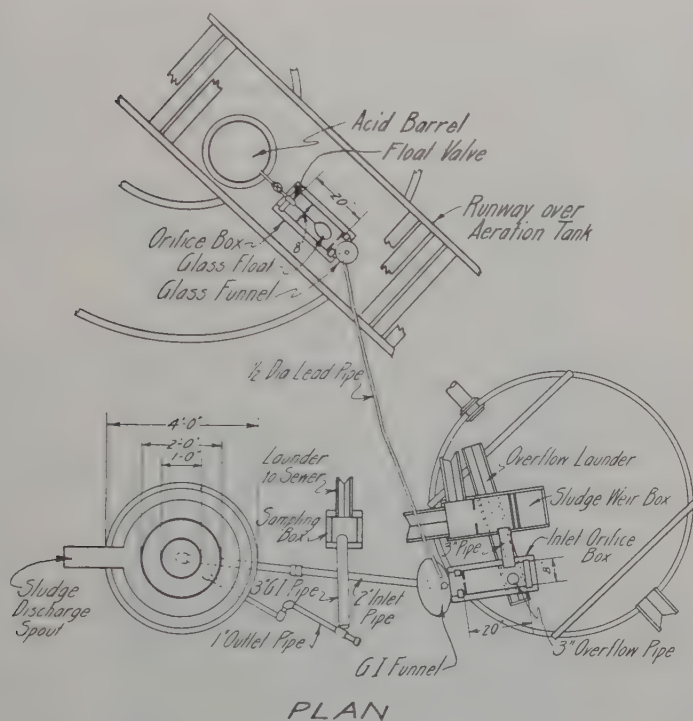


FIG. 1 — ACID HEAT FLOTATION PLANT.

perimental work is still being done on this problem, particular attention being given to preliminary processes which will dewater the sludge sufficiently to make subsequent treatment feasible and economical. In this connection, a recent process, acid heat flotation, was quite thoroughly tested at New Britain through the courtesy of the Dorr Co., of New York City, and a brief description of the plant and summary of results may be of interest.

THE ACID HEAT FLOTATION PROCESS.

The process consists essentially of first adding acid to the sludge and then heating the mixture. With proper design and operation, the results are twofold: first, the actual contraction of the sludge particles, and second, the flotation of these particles to the surface of the tank, where further dewatering and contraction takes place.

In the tests at New Britain both sludge and acid were fed from constant head orifices to a large funnel discharging into the inlet pipe of the flotation unit. (Fig. 1 & Fig. 2.) This unit was a galvanized iron tank 6.5 ft. deep and 2 ft. in diameter, set inside a four foot diameter wooden tank. Concentric with the other tanks and at the bottom was a small galvanized iron tank 3.5 ft. high and 1 ft. in diameter, forming a small reaction chamber. A small spiral coil, fed with live steam, was placed in this chamber. The inlet to the unit was through the bottom of the reaction chamber, the sludge flowing upward past the heating coil, the effluent being taken out at the bottom of the tank outside the reaction chamber. After heating, the sludge particles continued to float to the surface, overflowing into a collecting launder which discharged into a cart. (Fig. 3.) The unit as described was operated on the continuous flow principle, treating the sludge at a rate of 4 150 gallons per day or 173 gallons per hour. During the last five consecutive days of the flotation tests, the operation of the process was practically uninterrupted.

Average results over the entire testing period of about two and a half weeks were briefly as follows: The moisture content was reduced from 99.55% to 88.2%, the volume of sludge being reduced to one twenty-sixth, or 3.8% of the original volume.

The lowest moisture content for a daily composite sample of the floated sludge was 84.5%. On the dry basis, ammonia nitrogen averaged 5.85% and acid ether extract 16.2%. The average specific gravity of the floated sludge was 1.03. Of the total sus-



FIG. 2 — VIEW OF ACID FLOTATION PLANT.

pended solids in the influent sludge, 78.6% were recovered in the floated sludge, the remainder passing off in the effluent. Of the ammonia nitrogen input, 76% were recovered in the floated sludge and of the total iron input, 79%. These recoveries were not as high as would be desirable, but considering the experimental nature of the flotation unit, which was the first fairly large installation of its kind, perfect design and operation were not to be ex-

pected. The unit, furthermore, was operated 16 out of the 24 hours per day by unskilled labor. Due to these causes, there were times when considerable amounts of suspended matter were present in the effluent, which lowered the amounts of recovered constituents in the floated sludge. In spite of unfavorable conditions, however, the effluents were for the most part quite clear and often contained less than 100 p.p.m. of suspended solids, the lowest recorded being 55 p.p.m. Turbidities as low as 20

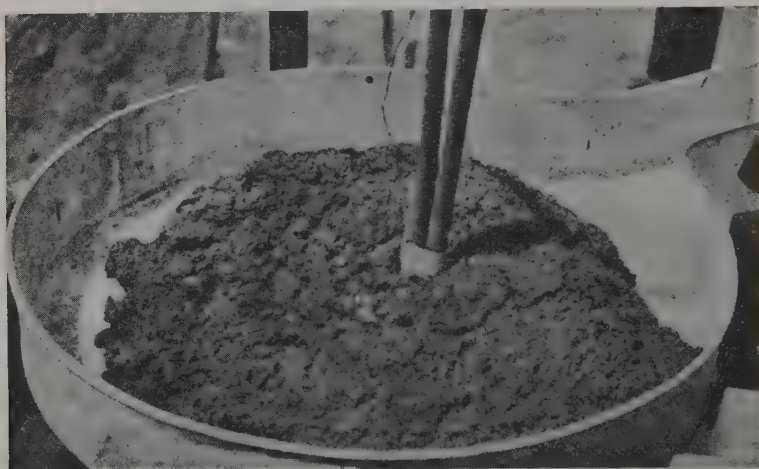


FIG. 3 — FLOATED ACTIVATED SLUDGE.

were often noted. In this particular effluent the suspended solids were approximately three times the turbidity, indicating that the suspended matter was quite heavy. Particles of grit and pieces of paper were, in fact, plainly visible in samples of the effluent. With a properly designed and operated plant, an effluent containing not more than 100 p.p.m. suspended solids might be expected and recovery of suspended solids and nitrogen in the floated sludge should be well over 90%.

Conditions at New Britain required the following operating rates: retention period in reaction chamber, 8 minutes; temperature of effluent 30 Co which was 150 C above that of the influent sludge; acid dosage, 1 c.c. H_2SO_4 , sp.gr. 1.84, per gallon of sludge.

The acid was usually applied in a 2% solution. Qualitative experiments indicated that both acid and heat were necessary, as neither alone produced proper flotation.

The floated sludge dewatered very readily when spread on rather hard impervious ground to depths varying from four to

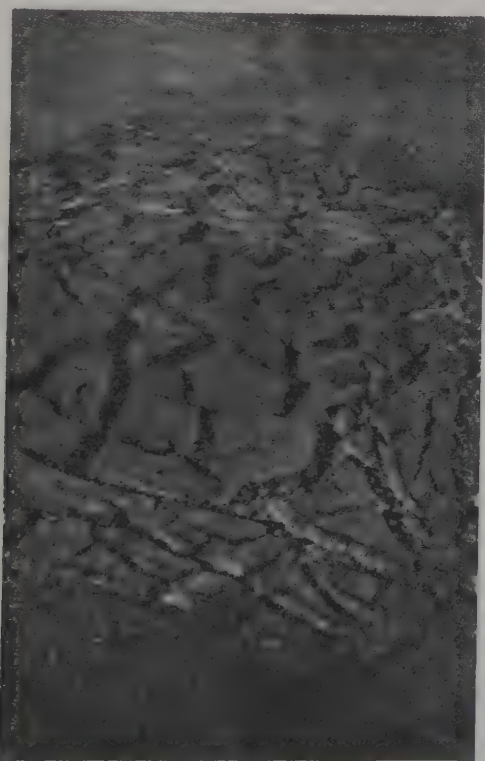


FIG. 4 — FLOATED SLUDGE ON DRYING BED

sixteen inches, dehydration cracks appearing in all piles within twenty-four hours. (Fig. 4.) The following moisture contents summarize the results of drying several cartloads of floated sludge in this manner.

Influent sludge, 99.4% moisture; floated sludge, 89.2%; 1 day drying, 77.1%; 2 days drying, 66.5%; 3 days drying, 59.7%; 3 weeks drying, 26.4%.

Most of the drying occurred during the first three or four days and was due largely to the drainage of water from the sludge. Evaporation of moisture seemed to predominate after that time. The result of these experiments was conclusive that the activated sludge could be concentrated and dewatered by the acid heat flotation process sufficiently to render it amenable to drying on beds. This would render the final drying, either by direct or indirect heat, considerably less expensive than for filter press sludge. It is only fair, however, to assume that filter press sludge could be dried equally well on beds, so that the saving in cost of heat drying between the two sludges is more apparent than real.

OTHER METHODS OF SLUDGE DEWATERING.

Drying on beds is the most common form of sludge treatment, but unfortunately this simple and economical method cannot be used for all sludges or in all localities. From our observation, grit, screenings, the sludges from settling, septic or Imhoff tanks usually dry readily to a spadable consistency. Some limed sludges also dewater satisfactorily on sludge beds, but with others clogging of the beds, apparently by lime soaps, is quite a problem. With Miles acid sludge, severe clogging of the beds took place. Untreated activated sludge, due to its rather gelatinous nature, quickly formed an impervious deposit on the surface of the sludge beds and the amount of drainage from the sludge was negligible.

Centrifuges have been successfully employed on sedimentation sludges in Germany, and experiments with the Basco ter Mer continuous centrifuge were made on the Milwaukee activated sludge. A low moisture cake, less than 80%, was obtained, but about half of the suspended matter was lost in the effluent. As this would result in undesirable pyramiding of the sludge if returned to the aëration tank, this method is not regarded as entirely satisfactory.

Filter presses have been successfully used to dewater limed sludges at several large plants in this country. Considerable work has also been done in filter pressing activated sludge, best results being obtained by acidifying the sludge prior to pressing. This method has produced sludge cake with as low a moisture

content at 75%, but rather cumbersome operation and expense of treatment are serious disadvantages. As to the relative merits of sludge flotation and filter pressing, we believe that the flotation process is much simpler to operate and very probably more economical than filter pressing, although the latter process will produce a sludge of somewhat lower moisture content. This last feature loses its importance, however, if the sludge is to be further dewatered on drying beds prior to heat drying.

At Milwaukee, in the early part of 1918, experiments were made by acidifying and settling activated sludge, reducing the moisture content in the sludge to about 91%. This method was apparently unsatisfactory, as no attempt was made to develop it into a practical and workable process.

The MacLachlan process, which is very recent, consists of burning sulphur, and forcing the fumes, mixed with live steam, through activated sludge. This process is being used at Houston, Texas, as a conditioner of the sludge prior to filter pressing, although the sludge, after treatment, is apparently amenable to drying on sludge beds. From the reports available, it appears that the process reduces the moisture content of the sludge from 98% to 95%, which is not as good as the results obtained with the other processes mentioned above. No data is given as to the percentage of suspended matter recovered in the sludge or the character of the effluent.

SUITABILITY OF VARIOUS SLUDGES FOR FERTILIZER BASE.

The concentration of ammonia nitrogen is the main criterion which determines the suitability of sludges for fertilizer base. Authorities quite uniformly agree that with less than 3% of nitrogen in the dried material, sludges are practically of no economic value as fertilizer. The Imhoff sludge tank at Baltimore, however, is a rather notable exception to this rule, as this sludge has been sold for fertilizer on the nitrogen basis, which usually was somewhat below 3%. At Rochester, too, the farmers are willing to pay sufficient to cover dewatering the sludge and haul it five or six miles for direct use on the land.

At New Britain, an interesting experiment was tried with the screenings. A plot of ground about three acres in area was sown to grass and fertilized with wet screenings applied in a thin layer. A surprisingly even and heavy growth resulted. For a number of years this same ground had been similarly sown but not fertilized and only sparse and patchy growths obtained. There was practically no odor or flies from the screenings and the results were so promising that the Superintendent of the Sewage Disposal Plant intends to make further attempts to utilize the screenings for fertilizer during the next planting season.

At New Britain also, considerable sludge is obtained from the sand beds, which up to the present time were dosed with raw sewage. The sludge was air dried and attempts were made over a number of years to use it for fertilizer. These, however, were unsuccessful and the present method of sludge disposal is by filling in spoil land.

Of the sludges here considered, however, we can dismiss as unsuitable for fertilizer base those from the grit chamber, Imhoff tank, and secondary sedimentation tank at New Britain and lime treatment at South Manchester, leaving only the activated and Miles acid sludges at New Britain and plain sedimentation at South Manchester as being possibly suitable for this purpose. Of these three sludges, the activated sludge, after acid heat flotation, had the highest nitrogen concentration, 5.85%. Plain sedimentation had 4.62% and the Miles acid 3.1%. The high nitrogen concentration in the plain sedimentation sludge is rather unusual for this type of sludge, but may be accounted for by the fact that the raw sewage contained considerable dye wastes, some of which had as much as 1 600 p.p.m. organic nitrogen.

Our experiments furnish some rather interesting data as to the varying nitrogen concentration of different sludges derived from the same sewage. Comparing the Imhoff tank and Miles acid sludges at New Britain, we find that the total amount of nitrogen per million gallons sewage in the former to be 11.1 lbs. and in the latter 9.6 lbs., yet the nitrogen concentration is greater in the Miles acid than in the Imhoff tank sludge. This is attributed to the solvent action of the acid on some of the sewage solids, preventing their precipitation into the sludge and thus resulting

in somewhat higher concentration of those substances actually in the sludge. Thus at New Britain, we have the anomaly in the Miles acid process of very small removal of nitrogen from the sewage but a relatively high nitrogen concentration in the sludge.

The reverse of this action is well illustrated on the South Manchester sludges. For example, the lime treatment sludge contained, in the form of lime precipitates, considerable extraneous matter other than sewage solids, so that we find the concentration of the actual sewage solids in the sludge to be proportionately reduced by the addition of these extraneous solids. Thus, while the nitrogen concentration of the plain sedimentation sludge amounted to 4.62%, that of the limed sludge was 1.48%, with a total recovery of nitrogen per million gallons sewage of 21 and 26 lbs. respectively.

Activated sludge at New Britain contained about three times as much nitrogen per million gallons sewage than either the Imhoff tank or Miles acid sludges. The more complete removal of suspended solids by the activated sludge process cannot be regarded as sufficient explanation for this circumstance, and it is our opinion that the high nitrogen concentration in the activated sludge is due to the assimilation of dissolved organic matter from the sewage by the sludge organisms and perhaps some fixation.

The suitability of sludge for fertilizer base is affected by factors other than the nitrogen concentration, such as availability of the nitrogen for plant food, the amount of phosphoric acid, the effect of fats and other chemical constituents of the sludge. Of the sludges here considered, however, the activated sludge appears to be the most promising for successful utilization as a fertilizer base.

SUITABILITY OF VARIOUS SLUDGES FOR FAT RECOVERY.

In general, sludges containing less than 15% fats are not considered suitable for fat or grease recovery. This, however, is a rather indefinite statement since varying amounts of fats are obtained depending upon the method used in making the analysis. Untreated sludge gives one result and sludges neutralized with sulphuric acid or treated with an excess of the acid give somewhat different results, due of course, to the action of

the acid on the saponified fats, and it is questionable whether or not these should be included. If fats are to be recovered at all, however, it is only natural to assume that the most complete recovery possible is meant, and for this purpose, as at Bradford, England, the sludge would be acidified before extracting the fats. In this case, therefore, the most important test would be the acidified ether extract and the present discussion assumes that sludges containing more than 15% acidified ether extract are tentatively suitable for fat recovery. With the exception of the grit, and possibly the screenings, all the sludges here considered contained more than 15% acid ether extract, the highest being from the grit chamber scum, which contained 66.5%. Plain sedimentation at South Manchester contained 37.5% and the Miles acid at New Britain 30.3%. Imhoff tank, secondary sedimentation tank and activated sludge each contained approximately 20% acid ether extract. Under present market conditions, it is doubtful if the extraction of fats from sludges of ordinary domestic sewages can be economically accomplished even with a concentration of over 15% acid ether extract. For certain industrial wastes and extraordinary sewages, such as at Bradford, England, fat extraction might be profitable. It has been stated, however, that one of the advantages of the Miles acid process is that the sludge is much more suitable for fat extraction than other sewage sludges, mainly because of its higher fat concentration. At New Britain, while the concentration of fats was higher in the Miles acid sludge than in the Imhoff or activated sludge, in actual operation after drying the sludges it is quite possible that there would not be any great difference in the suitability of these sludges for fat extraction due to concentration. As to the Miles acid sludge being superior to the other New Britain sludges, this is at least doubtful, even if sewage treatment is to be viewed from the standpoint of fat recovery rather than character of effluent. There can be no question that Imhoff tank treatment is considerably simpler and cheaper than Miles acid treatment, yet we find that Imhoff tank sludge, after three months storage, contained 67.2 lbs. plain ether extract per million gallons sewage while the Miles acid sludge contained 65.5 lbs. As for the acid ether extract, the Imhoff tank sludge contained 91.5 lbs. per mil-

lion gallons sewage and the Miles acid 93.4 lbs. The fat content of the activated sludge was almost double that from either the Imhoff tank or Miles acid, plain ether extract being 105.3 lbs. and acid ether extract 156.2 lbs. per million gallons sewage. As far as ultimate fat content is concerned, there is but little difference between the Miles acid and Imhoff tank sludges, while the activated sludge contains considerably more than either, in spite of the fact that the concentration in the Miles acid sludge is about 30% greater than in either of the other two.

SUMMARY.

In general, our experience in Connecticut is that where area is available, as at New Britain, air drying and final disposal on spoil land is the simplest and most economical method of handling the sludges from plain sedimentation, Imhoff tanks, secondary sedimentation tanks and perhaps lime treatment. It is true that more or less offensive accumulations of sludge would be developed, which, under certain conditions, would be a nuisance, but better and more expensive disposal would only be warranted by the assurance of recovery values that will, in part, offset the increased cost. The outlook for this, with the sludges just mentioned, is, however, not very promising.

Wet screenings, when applied to the land for fertilizing purposes, gave surprisingly good results. The experiment, however, was not carried far enough to be conclusive, and more information is necessary to determine how feasible it is.

For most limed sludges, filter pressing would probably be necessary. These sludges, apparently, do not offer much hope of successful treatment for either fertilizer purposes or other utilization.

A practical and economical method of dewatering Miles acid sludge was not developed. The preëminence of this method of treatment for producing a sludge particularly suitable for fat extraction was not shown.

Activated sludge, after acid heat flotation, air drying and heat drying would be readily adaptable for use as a fertilizer base. In the dewatering of activated sludge we believe that acid

heat flotation possesses certain advantages, such as simplicity of operation, elimination of filter pressing and saving in cost of final heat drying. It probably will not reduce the moisture content as much as either filter pressing or centrifuging, but apparently it will be cheaper than either of these methods.

For localities which require complete inoffensive disposal of sludge, irrespective of cost, Imhoff tank sludge, activated sludge and Miles acid sludge could be dried and degreased and undoubtedly recovery values sufficient to cover part of the cost of treatment obtained. Existing conditions at each locality would decide the method of treatment to be adopted. Where only partial treatment of sewage is necessary, economy would indicate selection of the method producing an effluent and sludge similar to those from the Imhoff tank. Where a greater degree of purification is required, then activated sludge or the Imhoff sprinkling filter system, either with or without recently developed modifications, would be selected.

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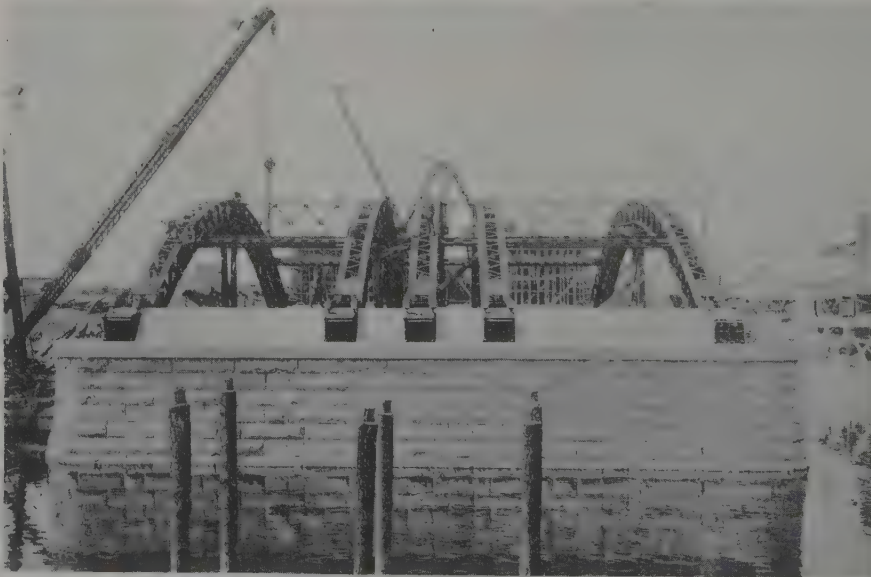
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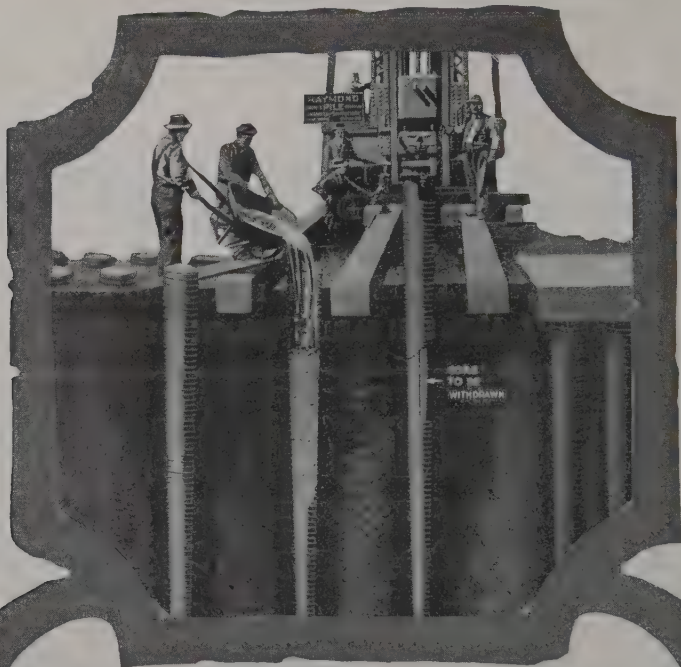
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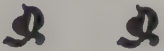
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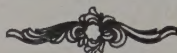
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